M6 MERGING BATHYMETRIC AND OPTICAL CUES FOR IN-DETAIL INSPECTION OF AN UNDERWATER SHIPWRECK

Ricard Campos[167], Nuno Gracias[29], Ricard Prados[168] and Rafael Garcia[30]

Abstract
We present a multimodal representation for mapping old underwater shipwrecks, in which bathymetric and optical data are joined together in a single 3D model. We use 3D smoothing and decimation techniques in order to alleviate possible aberrations on the original data and generate a light weight faithful representation respectively. The generated model can be visualized in common 3D CAD tools for further exploration and manipulation.

Keywords – bathymetry, mosaicking, smoothing, decimation.

I. INTRODUCTION

The wide variety of sensors carried by oceanographic vehicles provides the possibility of representing the ocean floor in many different ways. Two of the most used representations are bathymetry and optical mapping. While bathymetries usually map large areas (with resolutions typically in terms of several meters), and provide an overview of the surveyed site, optical mapping is often used for in-detail exploration (resolution of mm), and covering smaller areas. However, underwater robots carrying down-looking cameras and side-scan sonars and flying at low altitude offer the opportunity of mapping the same zone using both techniques. In this case, bathymetric and optical data can be merged together in order to provide further information than separately. For this reason, this paper aims to create a generic 3D model joining both information sources.
The surveyed area presented in this article corresponds to a French shipwreck named La Lune. This 38m long vessel sunk over the coast of Toulon in the XVIIth century, but its remains are still well preserved, causing this area to be of great interest for archaeologists.

II. BATHYMETRY PROCESSING

Bathymetry manipulation usually consists in considering the depth readings as pixel values, and noise smoothing is normally carried out using image processing techniques. Since we want to create a generic virtual model, we will explore the possibility of using renowned 3D manipulation techniques instead. The bathymetry is represented in a regular grid, with depth readings on each cell. In order to change into a surface 3D model, the cells in the regular grid forming the bathymetric map are triangulated by transforming each of them into two triangles.
Depending on the accuracy of the bathymetry, the resulting model can be quite noisy. In order to alleviate this problem, a Laplacian smoothing method was used. The Laplacian process moves a vertex to the mean position described by its neighbors on the mesh and itself. This procedure is applied n times until the desired smoothing is achieved (n=2 was enough for the current dataset).
Obviously, the naive triangulation approach followed generates a large quantity of triangles, despite the underlying geometry in the bathymetry may actually be represented faithfully using fewer triangles. Basically, planar (or almost planar) areas of the model should be represented with a smaller number of triangles than areas showing high curvature changes, which are more informative. For this reason, we decided to apply the quadric error metrics decimation procedure [1]. The method of quadric error metrics offers a good tradeoff between geometric accuracy and computational cost. In this method, the error at a vertex is described using a 4×4 matrix Q that represents the sum of squared distances from a vertex to the planes defined by the neighboring triangles as vTQv. At each iteration, the edge with smaller error (being the sum of the error of its endpoints) is removed using an edge collapse operation. In order to update the error metric of the vertex resulting after edge collapse, the quadrics Q of the original vertices are directly summed. This simple updating operation makes the method achieve a fair computational cost. Fig. 1 (a-c) shows the results of the different steps described so far. One can observe that even in this case, where the decimated version contains just the 25% of the original number of triangles, the shape is correctly preserved.

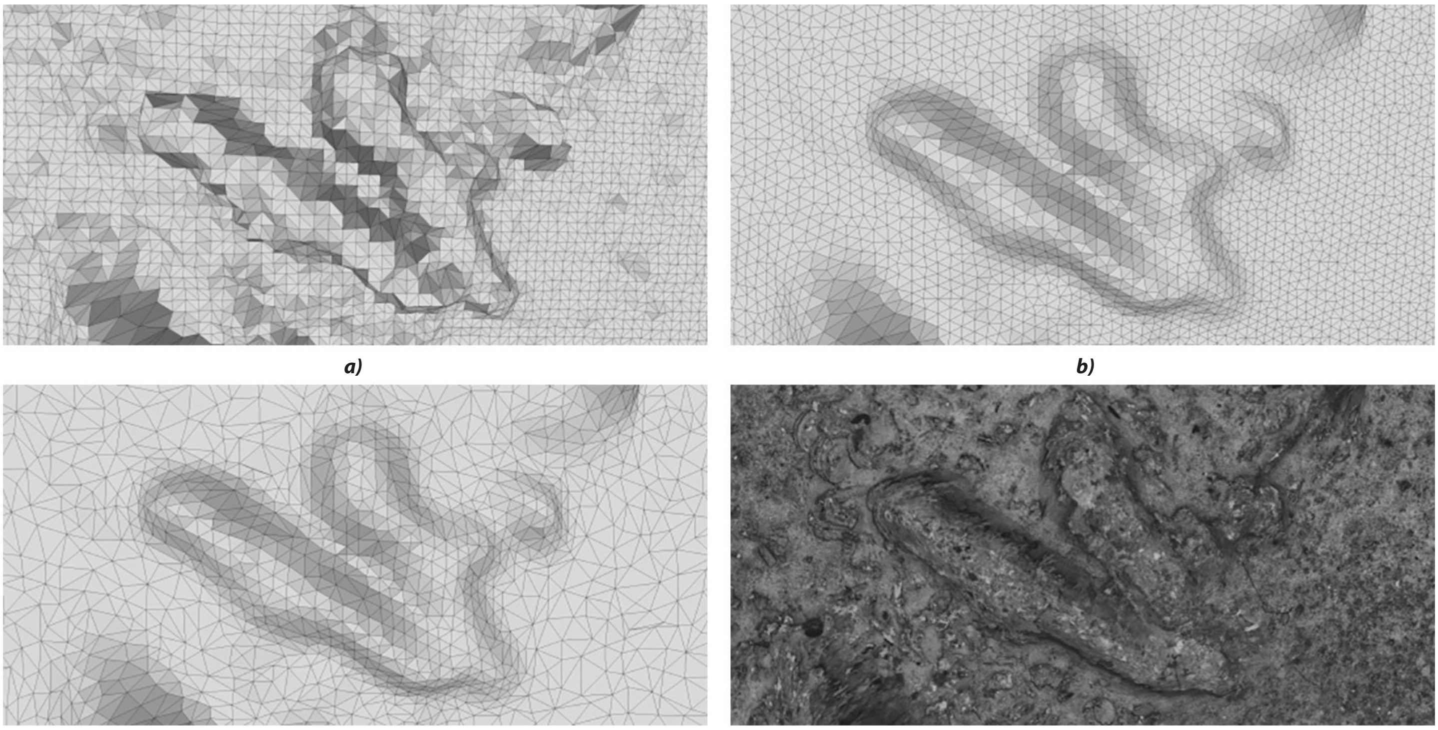
III. BATHYMETRY TEXTURING USING THE MOSAIC

Once the bathymetric map was built based on the state-of-the-art processing pipeline, a 2D mosaic of the area was constructed by using image-to-bathymetry correspondences as constraints for the mosaic optimization [2]. Being both representations georeferenced, vertices forming the triangles of the processed bathymetry have a direct mapping with the coordinates of the mosaic, so we can use the mosaic directly as texture for the above defined 3D model. There exist a fix transformation matrix (in the form of an absolute homography) between the world UTM coordinates and its corresponding pixel in the mosaic (wTm) or the vertex in the processed bathymetry (wTb). Thus, each of the vertices pb (the 3rd coordinate is ignored) from the bathymetry is transformed using pw= wTb pb. Then, we find the projection of this global coordinate into pixels on the mosaic by using pm= wTm-1 pw. Finally, these pm pixel coordinates are transformed and normalized with respect to the sizes of the mosaic. This last normalization provides invariance in case of scaling the texture map. Finally, both the model and the texture map are represented following the OBJ standard, allowing its processing in most CAD systems. Fig. 2 shows how the resulting model improves the original representation.

IV. CONCLUSIONS

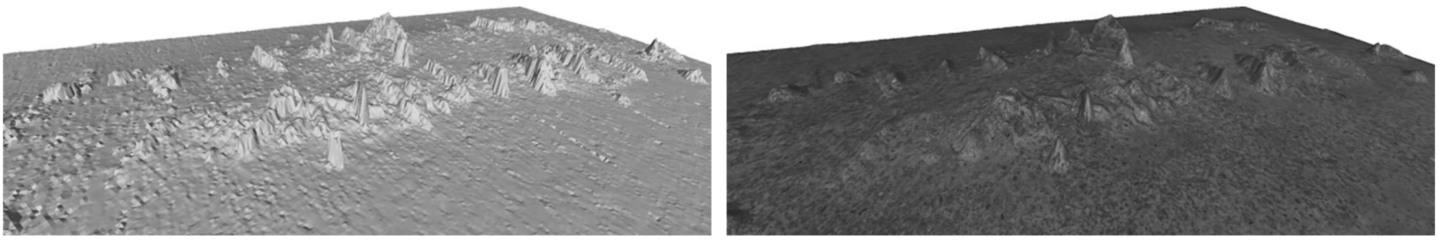
We have presented the merging of a bathymetric and optical map in a single 3D model, optimizing as well its appearance (using smoothing) and space requirements (using decimation). The resulting multimodal map allows the archaeologists not only to recognise the cannons, which are clearly visible in the original bathymetry, but also the smaller structures that were not captured by the bathymetry, but were faithfully represented in the optical mosaic.

REFERENCES
[1] M. Garland and P. S. Heckbert, "Surface simplification using quadric error metrics," in Proceedings of the 24th annual conference on Computer graphics and interactive techniques, ser. SIGGRAPH '97. New York, NY, USA: ACM Press/Addison-Wesley Publishing Co., 1997, pp. 209–216.
[2] N. Gracias, P. Ridao, R. Garcia, J. Escartin, M. L'Hour, F. Cibecchini, R. Campos, M. Carreras, D. Ribas, N. Palomeras, L. Magi, A. Palomer, T. Nicosevici, R. Prados, R. Hegedüs, L. Neumann, F. de Filippo and A. Mallios, "Mapping the Moon: Using a lightweight AUV to survey the site of the 17th Century ship 'La Lune'" in Proceedings of the IEEE OCEANS Conference (in press)



a) *b)* *c)* *d)*

Fig.1 . Close-ups corresponding to the same part of the map (two nearby cannons): (a) shows the original bathymetry, (b) the smoothed version, and (c) the decimated version. Finally, (d) shows the triangulation of (c) with the mosaic as texture.



a) *b)*

Fig. 2. The original bathymetry is illustrated in (a), while (b) shows the processed model with the mosaic as texture.